FORESTRY

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THE STATE OF SPRUCE STANDS IN THE UDMURT REPUBLIC

Research article

Abstract

The article presents materials on the dynamics of spruce stands in the zone of coniferous-deciduous forests and in the south taiga zone of the European part of the Russian Federation, on the territory of the Udmurt Republic.

In the process of the research, the information from the state forest register for the Udmurt Republic from 2009 to 2015was analyzed. In order to assess the state of spruce forests, trial areas were laid in various forestry zones. It is shown that the largest reduction in the area of spruce stands is observed in the southern part of the Republic, in comparison with the Northern part, which is located in a different landscape zone. According to the data of the enumerationestimation, a high content of dry wood was noted, that exceeds the volume of raw-growing forest. As a result of research on trial areas, spruce individuals that have a good life condition along with dead trees were identified, which indicates the individual characteristics of the surviving plants. Thus, in the zone of active distribution of xylophages the surviving individuals have an increased content of tannins in the wood.

Keywords: Spruce stands, dynamics, absolute completeness, dead wood, wood stock, succession, stability, tannins.

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СОСТОЯНИЕ ЕЛОВЫХ НАСАЖДЕНИЙ В УДМУРТСКОЙ РЕСПУБЛИКЕ

Научная статья

Аннотация

В статье представлены материалы по динамике еловых насаждений в зоне хвойно-широколиственных лесов и в южно-таежной зоне Европейской части РФ, на территории Удмуртской Республики. В процессе исследования проведен анализ информации Государственного лесного реестра по Удмуртской Республике с 2009 по 2015 гг. С целью оценки состояния еловых лесов были заложены пробные площади в различных лесохозяйственных зонах. Показано, что наибольшее сокращение площади еловых насаждений наблюдается в южной части республики, в сравнении с северной частью, располагающейся в иной ландшафтной зоне. По данным перечислительной таксации отмечено высокое содержание сухостойной древесины, которая по объему превышает запас здоровоголеса. В результате исследований на пробных площадях выявлены особи ели, имеющие хорошее жизненно состояние на ряду, с отмершими деревьями, что свидетельствует об индивидуальных особенностях выживших растений. Так в зоне активного распространения ксилофагов у выживших особей отмечается повышенное содержание танинов в древесине.

Ключевые слова: Еловые насаждения, динамика, абсолютная полнота, сухостой, запас древесины, сукцессия, устойчивость, танины.

1. Introduction

Spruce stands form evergreen dark coniferous forests of the Northern hemisphere with significant reserves of wood. In the Russian Federation, the main areas of spruce plantations are located in the North of the Russian plain, where they form the landscape of the European taiga [1].

A significant deterioration in the condition of dark coniferous forests, which in some cases is accompanied by their drying up, has been manifested throughout the Northern hemisphere. This process is very dynamic and covers the entire boreal zone from Europe to the North American continent, affecting all forest-forming species [2], [3].

The causes of forest degradation and desiccation may vary. Some authors believe that forest damage is caused by environmental pollution [4], while not excluding the role of natural stress factors.

Although it should be noted that the causes of drying up of dark coniferous forests are the result of the following leading factors: uneven precipitation, waterlogging of soils, the spread of parasitic fungi and the dynamics of xylophages. An important factor is the edaphic conditions formed under the influence of coniferous trees, namely the pH value of the soil solution [5].

However, the scale of boreal forest degradation, which affects all forest- forming species, suggests global changes occurring in the biosphere under the pressure of anthropogenic influence [6], [7], [8], [9].

Mass drying of spruce trees on a large area of the European part of the Russian Federation after abnormally high temperatures in 2010 caused considerable interest of researchers in the problem of studying the stability of spruce stands [10], [11].

This problem is also relevant for Udmurtia, where the share of coniferous species is quite high.

The purpose of the research was to study the dynamics of the area occupied by spruce plantations of the Udmurt Republic and assess their condition.

Research tasks:

1. To track the dynamics of the areas of spruce stands during their mass drying;
2. To carry out the laying of trial areas in places of mass drying of spruce stands on the basis of the obtained data on the dynamics of spruce stands;
3. To determine the taxing parameters of the plantings and their sanitary condition on the test areas.

The study area is located in the European part of Russia, in the basin of rivers the Kama and the Vyatka, West of the Ural Mountains, between the Parallels of 56°00' and 58°30' North latitude, meridians 51°15' and 54°30' East longitude. The area of the Udmurt Republic (hereinafter – UR) is 42.06 thousand km2. The territory of UR is strongly stretched from North to South by about 320 km, from West to East – by 200 km. the Large length from North to South and the heterogeneity of the landform cause significant differences in temperature, humidity, wind conditions, precipitation and duration of sunshine in the Northern and southern parts of the Republic. In this regard, the territory of the UR is located within two landscape zones: taiga (boreal/south taiga zone) and subtaiga (boreal-subboreal/zone of coniferous-broadleaf forests). The zonal border coincides with the Northern border of the range of Quercus and Corylus. it is conventionally drawn between the localities of the Republic: Vavozh - Nylga – Izhevsk-Votkinsk (fig. 1) [12].

Udmurtia is a forest region with a forest area (as of 01.01.2018) of 2,065,600 ha. the Average forest cover of the territory is 46.2%, and its distribution across the Republic is uneven and varies from 6.9% in the South to 72.5% in the North.

The ratio of areas of coniferous and soft– leaved species is almost the same and is 51% – coniferous and 49%- soft - leaved. By species composition, spruce and birch stands account for 790.7 and 669 thousand hectares, respectively.

Dark coniferous stands are concentrated in the North of the Republic and make up 74% (587,027 ha), while in the South of Udmurtia they account for 26% (204,009 ha).

2. Materials and methods of research

The study of the dynamics of the areas occupied by spruce plantations was conducted on the territory of the Udmurt Republic from 2009 to 2015. Changes in the areas of spruce plantations were based on the analysis of fundamental materials (materials of the state forest register – form 1.8 (hereinafter – SFR)) provided by the Ministry of natural resources and environmental protection of the Udmurt Republic. The General characteristics of the forest fund of Udmurtia are presented based on the study of the Forest plan [13].

To assess the taxational parameters and condition of spruce stands, test areas of 100×100 m were laid. Test areas (hereinafter referred to as TA) were laid in spruce stands, in places of their active drying, in acidic forest types (Eac). To assess the state of the plantings, an enumerative taxation method was used, which took into account trees of all categories of condition, including dead wood and fallen trees.

The main taxational parameters of the plant (average diameter, average height, average age, completeness, composition) were determined by a generally accepted method. When taxing the plantings, the distribution of trees by thickness steps was not carried out, in connection with the fact that the productivity of the plantings was determined by the method of B. D. Zhilkin. This method is based on the distribution of trees into classes relative to the average diameter of the plant: class I – 1.46 and higher, class II – 1.45...1.16, III – 1.15...0.86, IV – 0.85...0.76, class V – 0.75 and less. Class I includes very large trees, class II – large, class III – medium, class IV – small, and class V – very small. The wood stock was determined by the formula proposed by prof. N. P. Anuchin for shade- tolerant breeds [13].

$$M=10\times\sum G+0{,}4\sum G(H-21) \quad (1)$$

To assess the state of spruce on the TA, the content of tannins in the wood of Siberian spruce (PiceaobovataLedeb.) was studied.

In order to select wood for further research the trees in the sample areas were divided into three groups:

- good living condition-these are trees whose crown is thick or slightly ragged, needles are green/light green; individual branches are withered;
- satisfactory life condition-the crown of such trees is openwork and sparse, there are light green needles, growth is weak, there are damages to the trunk;
- unsatisfactory life condition-yellowish needles, drying of branches up to 2/3 of the crown; fruit bodies of tinder mushrooms, the presence of hollows, dead individuals.

Core sampling was performed using a Haglof-350 age drill at a height of 0.3 m from the root neck of the tree. Sample preparation of wood samples for extraction was carried out in accordance with TAPPI [15]. The tannin content was determined by hot distillation with distilled water in a Soxhlet apparatus, followed by determination of the content on a PE-5400UF spectrophotometer at a wavelength of 277 nm [16].

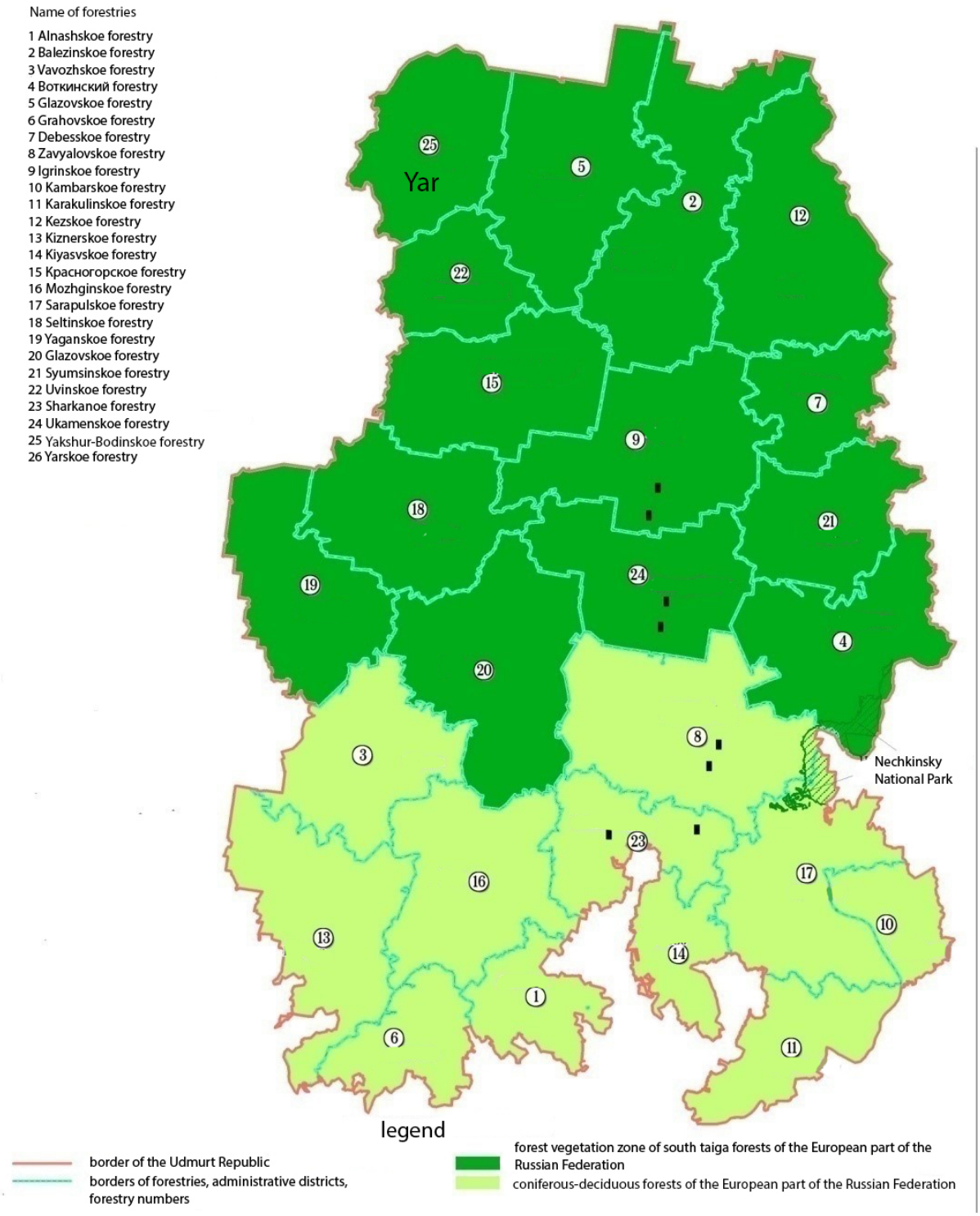

Figure 1 – Map of the location of trial areas on the territory of the Udmurt Republic (M 1:1 500 000)

Statistical processing of the obtained data was carried out using The Statistica 5.5 package of statistical programs. Cluster analysis and multivariate variance analysis (LSD-test multiple comparison method) were used to interpret the obtained materials.

3. The research results

Forests in UR are managed by the Ministry of natural resources and environmental protection of the Udmurt Republic. Geographically, all the forests of the Republic are divided into 25 forest districts, 11 of them are located in the zone of coniferous and broad-leaved forests, and 14 are located in the taiga zone. Despite the large areas of forests in Udmurtia, the last forest management was carried out in 1995-1997. However, partial forest management by tenants on lease plots is carried out

and this updated information is reflected in the state forest register. In this regard, the dynamics of spruce stands was studied based on the study and generalization of data from the SFR.

Analysis of SFR data showed that the area of spruce stands in Udmurtia from 2009 to 2015 decreased by 8% (65,400 ha).

A significant reduction of forests during the analyzed period occurred in the zone of coniferous-deciduous forests and amounted to 15% (29,728 ha). In the taiga zone, the total decrease in the area of spruce stands was 6% (35,959 ha) (tab.1).

Table 1 – Change in the area of spruce stands by year in the Udmurt Republic (% of the area in 2009)

№	The name of the forest area	2010	2011	2012	2013	2014	2015
The zone of coniferous-broad-leaved forests							
1	Alnashskoe	0,0	99,0	98,0	93,0	90,5	88
2	Vavozhskoe	100,3	100,4	85	84,8	84,5	84,0
3	Grahovskoe	101,1	85,6	109,8	109,5	109,4	109,7
4	Zavyalovskoe	96,5	96,9	96,8	96,7	96,6	86,8
5	Kambarskoe	101,8	102,7	103,1	103,5	104,2	104,5
6	Karakulinskoe	124,4	124,2	123,8	122,8	94,2	94,0
7	Kiznerskoe	91,4	91,2	89,9	89,8	89,8	88,4
8	Kiyasvskoe	50,9	51,0	51,8	51,9	51,2	51,9
9	Mozhginskoe	98,8	98,4	97,7	97,2	96,7	70,9
10	Sarapulskoe	102,1	103,1	102,3	102,8	103,6	87,7
11	Yaganskoe	100,3	100,0	99,7	99,3	99,0	98,5
The taigazone							
1	Balezinskoe	100,4	100,5	100,4	100,5	100,5	100,7
2	Votkinskoe	100,1	100,3	98,0	97,6	96,8	96,3
3	Glazovskoe	100,1	100,4	99,5	99,2	99,2	98,9
4	Debesskoe	100,6	100,6	100,4	100,3	98,4	98,6
5	Igrinskoe	100,1	92,5	92,5	92,7	92,8	92,7
6	Kezskoe	100,4	100,7	100,7	100,5	100,3	100,1
7	Krasnogorskoe	100,2	100,5	100,6	100,7	100,8	97,3
8	Seltinskoe	100,2	100,4	100,5	100,4	96,5	92,1
9	Syumsinskoe	100,7	98,8	87,9	86,6	87,5	85,5
10	Uvinskoe	100,5	101,1	92,9	80,6	80,1	79,7
11	Sharkanoe	99,9	99,8	99,7	99,3	98,7	98,4
12	Ukamenskoe	100,2	100,3	100,5	100,8	100,9	100,9
13	Yakshur-Bodinskoe	100,5	101,1	101,2	101,4	95,8	92,2
14	Yarskoe	99,7	77,2	77,3	77,0	77,1	77,4

In the South, in the area of coniferous -broadleaved forests, the biggest decline of spruce stands is observed in Kiyasvskoe (48%), Mozhginskioe (29%), Vavozhskoe (16%), Zavyalovskoe(13%) and Alnashskoe (12%) forest areas. In the North of Udmurtia, it is observed in Yarskoe (23%), Syumsinskoe (14%), Uvinskoe (20%), Igrinskoe (7.8%) and Yakshur-Bodyinskoe (7.9%) forest areas.

In those forest areas where the greatest reduction in dark coniferous stands was observed, the age structure was analyzed (by age groups). In the zone of coniferous -deciduous forests in the Alnashskoe, Vavozhskoe, Zavyalovskoe, Kiyasovskoe and Mozhginskoe forest areas, there is a reduction in the area for all age groups from young to overaged. The most significant changes in the area of spruce stands across the entire age spectrum are observed in Kiyasovskoe (from 12.7% to 73.6%) and Mozhginskoe (from 11.6% to 32.0%) forest areas.

In the taiga zone, the largest reduction in the area is observed in the group of young trees (11.26...28.99%), while in the middle- aged and in the group of mature and overaged trees changes are insignificant, except for the Uvinskoe and Yarskoe forest areas.

Changes in the area of spruce stands, including by age group, may be related to both economic measures (increase in the volume of cutting) and in connection with updating the SFR data (the transfer from one age group to another). However, analyzing the economic work carried out in the forest fund for cutting down forest stands (the development of the estimated cutting area for coniferous trees is 69%) and reforestation measures (the reforestation is 102%), it can be argued that the reduction of spruce stands in Udmurtia is associated with the deterioration of their sanitary condition. [13].

The unsatisfactory state of dark coniferous stands is caused by the unfavorable phytopathogenic background. In our opinion, this is due to changes in natural and climatic conditions in the Republic. Thus, according to hydrometeorological

observations for the period from 2006 to 2015, the total amount of precipitation during the growing season decreased, while the air temperature increased (on average by 1.2 0C). Such climate changes have led to an offset of the boundary zone to the North between the zone of coniferous-broadleaf forests and the zone of taiga forests [13]. A decrease in precipitation and an increase in temperature favorably affects the competitive abilities of soft-leaved species, while negatively affecting the vital indicators of coniferous species.

In order to determine the state of spruce stands, we have laid down TA in forest areas with a high proportion of spruce forests located in two forestry zones. In the zone of coniferous-broad -leaved (mixed) forests, TA were laid in Zavyalovskoe and Yaganskoe forest areas, in the southern taiga zone there were Yakshur – Bodyinskoe and Igrinskoe forest areas.

Taxational parameters of plantings on TA are presented in table 2.

Table 2 – Average taxational characteristics of plantings on trial areas, (Udmurt Republic, 2019)

№ TA	Forestry, precinctforestry (quarter, plot)	$A_{ср}$±m., years	$H_{ср.}$ ±m, m	$D_{ср.1,3}$±m, cm	∑G, м²/га M, m³	∑G, m²/ha*	M, m³**	Composition Number of trees in the TA (%of shrinking and dead trees)
The zone of coniferous - broad -leaved forests								
1	Zavyalovskoe, Suburban (78,3)	70±2,3	21±0,6	27,9±0,4	10,7 107,0	14,9	67,2	9S1F+B 260 (47,7)
2	Zavyalovskoe, Suburban (158,3)	67±3,8	23±0,6	26,0±0,3	11,1 119,9	17,9	87,5	9S1F 324 (38,3)
1	Yaganskoe (115, 8)	60±1,7	18±0,5	25,9±0,8	6,0 52,8	16,6	93,8	10S+F 252 (50,8)
2	Yaganskoe (214, 8)	65±1,6	22±0,3	21,4±0,4	2,95 30,7	5,9	31,1	10S 155 (56,1)
Southtaigazone								
1	Yakshur-Bodinskoe, Selichinskoe (81,15)	77±1,1	18±0,4	22,2±0,4	10,1 109,12	13,4	29,3	7S1F1B1As 312(27,9)
2	Yakshur-Bodinskoe, Selichinskoe (86, 37)	74±1,6	23±0,4	26,8±0,1	17,7 191,2	26,0	89,9	9S1As+F 441 (42,6)
1	Igrinskoe, Chutirskoe (186,14)	69±0,7	19±0,9	22,9±0,3	19,8 182,16	22,7	26,0	8S2F 515 (13,6)
2	Igrinskoe, Чутырское (118/4)	70±0,7	19±0,9	23,9±0,2	26,0 239,2	27,7	15,73	9S1F 581 (12,6)

*Annex: * - absolute fullness, taking into account dead trees*

** *- is the stock of dead wood on the permanent plot*

According to the productivity of plantings Zavyalovskoe, Yakshur-Bodyinskoeand Igrinskoe forest areas belong to the III class. This class accounts for between 31% and 57% of the trees counted. On the TA laid down in the Yaganskoe forestry plantings are low-productive. In the first TA, 53% of trees belong to classes IV-V; in the second TA there are 74%, with no class I trees at all.

When comparing the diameters of living and dead spruce individuals, it was found that most of the dead trees have a trunk diameter above average. The phenomenon of shrinking of larger trees has also been noted by other researchers [5].

Plantings on TA in the zone of coniferous -deciduous forests are characterized by a low density of trees of the main tier, the fullness varies from 2.95 to 11.1 m^2/ha with a large number of dead trees (absolute fullness with deadwood is 5.9...17.9 m^2 / ha).

According to the enumerative taxation data, a fairly large stock of dry wood was found in all studied areas. Depending on theTA, its reserve is 31.1...93.8 m^3/ha, so the risk of forest fires occurrence and spread increases. On trial areas in the Yaganskoe forest area, the stock of dead wood exceeds the stock of live trees, and in the Zavyalovskoe forest area, dry wood accounts for more than 50% of the stock of live trees.

There is also a low level of completeness in the taiga zone, but as we move North, the completeness of plantings increases. Fewer dead trees were recorded on these test areas and, accordingly, the supply of dry wood.

The main cause of spruce death on the territory of UR is the spread of the bark beetle (Ips typographus) [13]. This is confirmed by our research. The characteristic uterine traces of xylophage were found on the dead trees.

Thinning of the main tree canopy on the TA in the zone of coniferous-deciduous forests, which is the environment-forming factor, led to a change in the plant community. The test areas under study have lost the main features of spruce forest ecosystems. In the living ground cover, forest non-moral grasses (European asarum (asagimeigoraeim L.), common sorrel (Oxalis acetosella L.)) begin to be replaced by field grasses (field sow thistle (Sonchusarvensis L.), cocksfoot (Dactylisglomerata L.), meadow bluegrass (Poa pratensis L.), hybrid clover (Trifoliumhybrídum L.) and others), which forms a dense sod that does not allow fir seedlings to take root. Coniferous undergrowth is absent (on trial areas in the Yaganskoe forest area) or present (on trial areas in the Zavyalovskoe forest area), but in insufficient quantity (less than 500

pcs/ha) and of poor quality (unreliable). From woody vegetation, common raspberries (Rubusidaeus L.), common mountain ash (Sorbus aucuparia L.), forest honeysuckle (Lonicera xylosteum L.) and silver birch (Betula pendula Roth.) are widely present. The latter begins to form the main tier.

It should be noted that in the course of the study on the trial areas, individuals of spruce that have a good physical condition were identified. Only some plants have exit holes on the trunk, but, in general, the condition of such plants (according to external morphological characteristics) is good.

In places of damage, such trees have abundant tarring. It is possible that the damage and death of some individuals and the good condition of others are associated with individual characteristics (physiological and biochemical properties of wood).

To assess the biochemical characteristics of spruce individuals of different life states, we determined the content of tannins in the wood.

Cluster analysis was used to interpret the data obtained. Cluster analysis allows you to combine the studied features into groups based on similar parameters (fig.2).

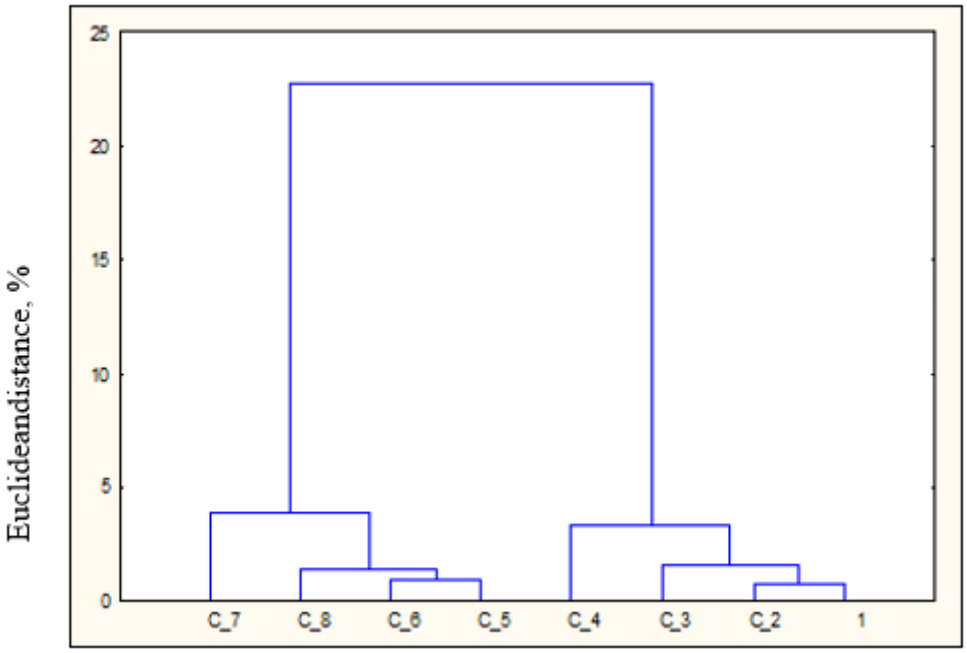

Figure 2 – The results of cluster analysis of tannin content in PiceaobovataLedeb wood. (1-Zavyalovskoe forest-in TA1, C_2-Zavyalovskoe forest-in TA2, C_3-Yaganskoye forest-in TA1, C_4-Yaganskoye forest-in TA2, C_5-Yakshur-Bodinskoe forest-in TA1, C_6-Yakshur-Bodinskoe forest-in TA2, C_7-Igrinskoe forest-in PP1, C_8-Igrinskoe forest-in TA2)

The analysis showed that the spruce individuals of different life states were divided into two clusters based on the tannin content. The first cluster includes individuals growing in the taiga zone, and the second cluster includes individuals growing in the zone of coniferous – broadleaf forests.

Then we used the variance analysis performed using the LSD-test multiple comparison method. The results of the variance analysis are presented in table 3.

Table 3 – The results of the LSD test. Influence of the place of growth and state on the content of tannins (Udmurt Republic, 2019)

	1	2	3	4	5	6
tannin content, %	6,08	6,43	3,47	1,20	1,891897	1,38
1		0,42	8,79E-08	1,28E-16	4,98E-14	5,75E-16
2	0,42		3,72E-09	6,97E-18	2,34E-15	3,02E-17
3	8,79E-08	3,72E-09		1,79E-06	0,00048	8,15E-06
4	1,28E -16	6,97E-18	1,79E-06		0,11	0,68
5	4,98E-14	2,34E-15	0,00048	0,11		0,24
6	5,75E-16	3,02E-17	8,15E-06	0,68	0,24	

Note: 1-good condition, zone of coniferous -deciduous forests; 2-satisfactory condition, zone of coniferous -deciduous forests; 3-unsatisfactory condition, zone of coniferous-deciduous forests; 4-good condition, taiga zone; 5-satisfactory condition, taiga zone; 6-unsatisfactory condition, taiga zone.

The analysis revealed that spruce individuals growing in the coniferous- broadleaf zone have a higher tannin content than individuals growing in the taiga zone. This difference may be due to the fact that the state of spruce stands in the taiga zone as a whole is better (a small number of dead plants) and no bark beetle damage was detected.

There are no statistically significant differences in the content of tannins in trees of different life conditions in the Northern regions of the Republic. In the zone of coniferous-deciduous forests, trees of unsatisfactory condition have a significantly low content of tannins in comparison with trees of good and satisfactory condition.

In our opinion, an increase in the content of tannins in wood is one of the factors of pest control. A higher concentration of tannins in spruce individuals, in the southern part of the Republic (the place of active reproduction of the bark beetle-typographer) contributes to the trees to withstand xylophages.

4. Conclusions

According to the average data, the reduction in the area of spruce stands on the territory of the Udmurt Republic from 2009 to 2015 was 8%. The largest reduction occurred in the zone of coniferous and broad-leaved forests and amounted to 15% and in the southern taiga zone, the decrease in area was 6%.

It should be noted that data on the area and dynamics of spruce stands are provided on the basis of form 1.8 of the state forest register, the information of which is reflected on the basis of updated data. However, the lack of modern field and remote surveys of plantings in Udmurtia does not allow us to obtain reliable information about them.

The trial areas were laid in the zone with the greatest reduction in the area of spruce stands, in forest areas with a high proportion of dark coniferous species, differing in the degree of reduction in the area of spruce stands, in places where they are mass drying up.

In terms of productivity, spruce stands belong to class III and IV. It is noted that most of the dead trees were highly productive and belonged to the I...III class. Plantings are characterized by low fullness, with a significant number of dead trees, the stock of wood, which can reach 93.8 m^3/ha.

Thinning of the main tree canopy led to a change in the plant community, which led to the beginning of successional processes.

As a result of research on trial areas, spruce individuals that have a good vital condition, along with dead trees were identified, which indicates the individual characteristics of the surviving plants. Thus, in the zone of active distribution of xylophages, the surviving individuals show an increase in the content of tannins in wood.

Conflict of Interest

None declared.

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Конфликт интересов

Не указан.

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